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THE TRAFFIC CAPACITY of the New York and Brooklyn Bridge Railway.

The Traffic Capacity

OF THE

New York and Brooklyn Bridge Railway.

BY

G. LEVERICH, C. E.

BROOKLYN, N. Y., 1889.

S. B. LEVERICH,
PRINTER,
51 JOHN ST., NEW YORK.

NOTE.

Early in the use of the New York and Brooklyn Bridge as an avenue between two great cities, those charged with its management began to realize that in certain features it was or soon would be, unable to adequately provide for the comfortable and prompt transport of the rapidly increasing traffic over its Railway; and from time to time as there was opportunity, thoughtful consideration, based upon the experience acquired, has been given to improvements for expanding the facilities of transit, as needed to meet the current demand until eventually the maximum capacity of the structure would be reached.

The following Paper contains a brief record of the action in this direction heretofore taken; a description of plans which have been adopted and of others now proposed; a discussion of the conditions and principles which in the judgment of the writer, determine an exhaustive treatment of the subject; and a record of the data thus far gained in the successful operation of the Railway, from which largely these conditions and principles were deduced.

The statements of fact herein contained, may readily be verified; for the conclusions and opinions derived therefrom and expressed, the writer is solely responsible.

G. LEVERICH,
Civil Engineer.

January, 1890.

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THE TRAFFIC CAPACITY

OF THE

New York and Brooklyn Bridge Railway.

1. The New York and Brooklyn Bridge is famous, the world over, as the result of engineering knowledge and constructive skill; it is unsurpassed in the boldness of its design, the magnitude of its proportions, the beauty of its appearance and the permanence of its structure. The only continuous link or avenue connecting the two largest American cities, its purpose is to convey safely, promptly and uninterruptedly, over its railway, roadways and footway, a greater part of the daily travel between these cities. Necessarily most of the passenger traffic is carried over the Railway; an ideal train service would be from centre to centre of the two cities, where a larger number of the passengers may easily reach and leave the line; it should be capable of quick expansion and contraction to suit at all times the fluctuating traffic, without delays at the stations or in transit, undue crowding on the platforms or in the cars, entirely safe for passengers and employees, and it should be rendered at a minimum operating cost. Such a service was included in the purpose of the bridge; how far it has been accomplished in the past or may be in the future, will be herein considered.

PRELIMINARY ESTIMATES OF TRAVEL.

2. James A. Perry, Managing Director of the Union Ferry Company, testified March 7, 1879, before the Assembly Committee on Commerce and Navigation, that in February 1878, the foot passengers over the five Union Ferries between New York and Brooklyn were counted; from the data thus obtained he estimated that 112 000 foot passengers were carried daily; of whom about 35 per cent. or 39 200 were between 5 and 7.30 o'clock, morning and evening, or 7 840 per hour of each of these five hours; also

that about one-half of the total foot passenger traffic or 56 000 daily, 19 600 between 5 and 7.30 o'clock morning and evening and 3 920 per hour, passed over Fulton Ferry.

3. In a Report on the Bridge Railway and New York Station prepared by F. Collingwood and the writer, before the present Stations were designed, and presented to the Trustees, January, 1881, an estimate of the probable traffic over the Bridge Railway was made, based on Mr. Perry's testimony. It was assumed that one-third of the foot passengers over Fulton Ferry during the crowded hours, or 6 500, were carried in the busiest hour, of which four-fifths, or 5 200, were in one direction and one-fifth, or 1 300, were in the other direction; that this would be the maximum traffic at first over the Bridge Railway, and that about 40 per cent. should be added to represent the probable future increase; whence it was estimated in the Report mentioned, that provision should be made to transport per hour 7 200 passengers in one direction and 1 800 passengers in the other direction. At that time this estimate was regarded by competent authority as unduly large.

TRAFFIC HANDLED.

4. The Bridge Railway was opened to public use September 24, 1883; the number of passengers carried each month since and the daily average per month, also the greatest and least number carried on any day of that month, as indicated by the sale of passage tickets, are given in Table I. It will be noticed that in March 1886, there was a large increase; this was due to a reduction of the fare from 5 to 3 and 2½ cents per passenger at that time.* For comparison, the Table is arranged in columns for each year beginning March 1.

5. In the number of passengers carried month by month and in the daily averages, there are great differences; the fluctuations of traffic from December 1, 1884, to December 22, 1889, in months of four weeks each, is exhibited graphically by the diagram, Fig. 1. It will be seen that the greatest and least numbers carried daily in each calendar year is generally during the inclement season, late in autumn or in the winter; and that year by year there is a steady but lessening increase.

* Tickets are sold in packages of ten for 25 cents and single tickets for 3 cents; the mean price received for a passage, based on a year's traffic is 2¾ cents. Except as hereinafter stated, the record of passengers carried is of the total number of tickets sold, and for single days therefore is not strictly correct.

AND DAY.

number with a dotted line.

Month	1883-8			1888-89.				1889-90.			
	Per Month.	Per Day.		Per Month.	Per Day.			Per Month.	Per Day.		
		Average.	Least.		Average.	Greatest.	Least.		Average.	Greatest.	Least.
March	.....	.....	37 892	2 488 892	80 287	113 249	32 868	2 794 670	90 151	115 354	41 312
April	.....	.....	54 067	2 593 104	86 436	106 589	56 041	2 933 776	97 793	159 259	56 908
May	.....	.....	43 914	2 618 501	84 468	105 134	53 464	2 931 172	94 554	143 685	54 878
June	.....	.....	50 552	2 437 560	81 252	102 972	45 722	2 665 589	88 853	110 581	52 969
July	.....	.....	34 686	2 274 071	73 357	89 742	46 222	2 532 665	81 699	99 252	44 415
Aug	.....	.....	48 018	2 266 785	73 122	90 425	40 033	2 654 273	85 622	113 018	53 465
Sept	.....	.....	56 494	2 512 024	83 734	111 578	37 782	2 881 277	96 043	126 856	57 413
Oct	477 700	15 410	54 699	2 859 697	92 248	119 026	50 863	3 231 775	104 251	137 642	44 239
Nov	561 520	18 717	48 238	2 701 560	90 052	117 507	38 451	3 141 165	104 706	137 131	47 139
Dec	600 440	19 369	42 765	2 857 096	92 164	119 597	40 278	3 209 798	103 542	.....	.....
Jan	663 840	21 414	31 115	2 790 751	90 024	114 204	34 263	*3 157 638	*101 859	.....	.....
Feb	723 740	24 956	46 765	2 540 564	90 734	116 864	47 252	*2 874 562	*102 663	.....	.....
Totals	3 027 240	19 916	.....	30 940 605	84 769	.....	.....	*35 008 300	*95 913	.....	.....

* Estimated.

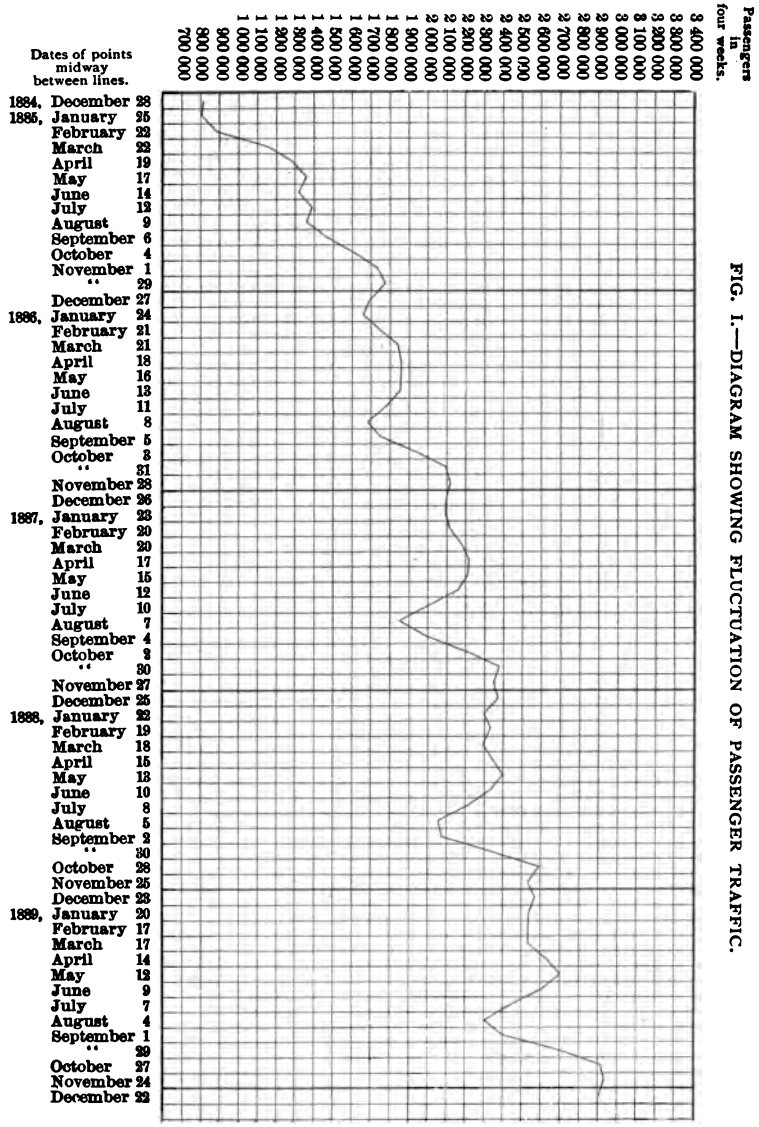


FIG. I.—DIAGRAM SHOWING FLUCTUATION OF PASSENGER TRAFFIC.

6. The total traffic from Brooklyn to New York per year or month is uniformly, and per day is usually, greater than from New York to Brooklyn, as shown by Tables II., III. and IV. Table II. gives the proportions of travel each way for the several years covered by Table I.

TABLE II.—PROPORTIONS OF TRAVEL IN EITHER DIRECTION.

As indicated by daily record of tickets sold.

Periods.	Passengers.			Per cent. of total number carried.	
	From New York.	From Brooklyn.	Total number.	From New York.	From Brooklyn.
Five months, begin'g Oct. 1, 1883.	1 297 420	1 729 820	3 027 240	42.8	57.2
Year " March 1, 1884.	4 079 489	5 155 201	9 234 690	44.2	55.8
" " " " 1885.	9 273 698	10 690 902	19 964 600	46.4	53.6
" " " " 1886.	11 812 111	13 504 137	25 316 248	46.7	53.3
" " " " 1887.	13 546 815	15 205 189	28 752 004	47.1	52.9
" " " " 1888.	14 822 451	16 118 154	30 940 605	47.9	52.1
Ten months " " " 1889.	13 925 259	15 050 901	28 976 160	48.1	51.9
Total for 6 years and 3 months ..	68 757 243	77 454 304	146 211 547	47.	53.

7. The traffic varies day by day as affected by the occasion or the weather. The greater number of passengers over the Railway in one day was on Tuesday, April 30, 1889; 159 259 were carried both ways, of which 74 028 or 46.5 per cent. were from New York and 85 231 or 53.5 per cent. were from Brooklyn. This was an extraordinary occasion; but as seen in Table I., the greatest number per day in each month since has increased; thus on Saturday, October 19, 1889, 137 642 were carried both ways or but about 14 per cent. less than on April 30, 1889. The number of passengers carried on other days and the relative proportions each way, as determined by actual count, are given in Tables III. and IV.

8. During the day of 24 hours, the traffic over the Railway ebbs and flows irregularly, greater in the morning from Brooklyn and in the afternoon from New York; for a part of each time the cars moving one way will be densely crowded and those moving the other way will be perhaps not one-fourth full; during intervening periods the travel in the two directions may be nearly equal. The

TABLE III.—PASSENGERS CARRIED ON CERTAIN DAYS.

As determined by actual count.

Day.	From New York.				From Brooklyn.				Total carried in 24 hours.	Train Service.	
	Maximum in one hour.	Between 7 a. m. and 7 p. m.	Between 7 p. m. and 7 a. m.	In 24 hours.	Maximum in one hour.	Between 7 a. m. and 7 p. m.	Between 7 p. m. and 7 a. m.	In 24 hours.		Time that the trains ran.	Hours that the trains ran.
1883, Oct. 18	1 420	5 950	1 270	7 220	1 560	7 840	1 440	9 280	16 500	6 a.m.–12 p.m.	18
1884, Feb. 27	2 174	7 070	2 090	9 160	3 073	1 780	2 060	13 840	23 000	6 a.m.– 1 a.m.	19
Mar. 25	2 325	8 990	2 290	11 280	2 765	11 740	2 220	13 960	25 240	" "	"
Apr. 28	2 405	9 180	2 440	11 620	3 090	12 220	2 260	14 480	26 100	5 a.m.– 1 a.m.	20
May 20	2 503	8 930	2 210	11 140	3 006	11 710	2 450	14 160	25 300	" "	"
June 25	2 480	8 060	1 820	9 880	3 950	9 690	2 670	12 360	22 240	" "	"
July 17	2 150	7 430	1 910	9 340	2 570	9 840	2 140	11 980	21 320	" "	"
Aug. 13	2 085	7 990	1 970	9 960	2 496	9 960	2 400	12 360	22 320	" "	"
Sep. 17	2 512	9 060	2 130	11 190	3 005	11 587	2 300	13 887	25 077	" "	"
Oct. 11	2 710	10 247	2 830	13 077	3 280	13 285	2 750	16 035	29 112	" "	"
Nov. 17	2 980	10 515	2 175	12 690	3 709	13 854	2 250	16 104	28 794	" "	"
Dec. 20	3 480	10 683	2 845	13 528	4 620	16 211	2 195	18 406	31 934	12 p.m.–12 p.m.	24
1885, Feb. 24	3 473	12 608	3 220	15 828	4 725	17 883	2 800	20 683	36 511	" "	"
1886, May 25	7 187	25 306	6 840	32 146	7 870	30 807	7 284	38 091	70 237	" "	"
1887, Nov. 29	9 402	33 516	9 200	42 716	10 068	40 721	7 693	48 414	91 130	" "	"
Mean per cents. in 24 hours.	22.3	79.5	20.5	100.	21.8	83.6	16.4	100.		Carried one way.	
	10.	35.5	9.1	44.6	12.1	46.3	9.1	55.4	100.	Carried both ways.	

number of passage tickets sold in each day of 24 hours is regularly taken and recorded; at certain times the number of passengers carried during specific hours has been counted and from the data thus obtained Tables III. and IV. were collated, showing the fluctuation and relative proportions of the daily travel at different periods. The mean per cents. in Table III. correspond quite nearly to similar per cents. for the several days mentioned. From this Table it will be seen that about 82 per cent. of the total traffic is carried in the 12 hours from 7 o'clock a. m. to 7 o'clock p. m., and about 22 per cent. in one-sixth of this time, the maximum morning and evening hour. The number of passengers each way carried each hour of

TABLE IV.—PASSENGERS CARRIED PER HOUR ON CERTAIN DAYS.

As determined by actual count.

Hours.	Tuesday, May 25, 1886.			Tuesday, Nov. 29, 1887.			Wednesday, Oct. 31, 1888.			Tuesday, Oct. 29, 1889.		
	From New York.	From Brooklyn.	Total.	From New York.	From Brooklyn.	Total.	From New York.	From Brooklyn.	Total.	From New York.	From Brooklyn.	Total.
12 P.M.–1 A.M.	320	155	475	389	197	586	467	298	765	615	267	882
1 A.M.–2 "	195	104	299	249	62	311	237	79	316	295	71	366
2 " 3 "	158	131	289	211	80	291	193	97	290	242	80	322
3 " 4 "	93	129	222	111	128	239	128	118	246	178	115	293
4 " 5 "	112	144	256	112	139	251	127	153	280	146	138	284
5 " 6 "	127	432	559	143	370	513	134	476	610	144	610	754
6 " 7 "	410	2 708	3 118	469	2 894	3 363	662	3 140	3 802	710	3 780	4 490
7 " 8 "	505	7 870	8 375	841	9 366	10 207	996	10 324	11 320	989	11 836	12 825
8 " 9 "	645	7 483	8 128	712	10 068	10 780	880	9 550	10 430	893	11 255	12 148
9 " 10 "	746	3 489	4 235	1 007	4 589	5 596	1 070	4 488	5 558	1 270	5 507	6 777
10 " 11 "	799	1 834	2 633	1 144	2 776	3 920	1 221	2 638	3 859	1 349	3 079	4 428
11 " 12 M.	968	1 450	2 418	1 333	2 267	3 600	1 436	2 275	3 711	1 625	2 205	3 830
12 M.–1 P.M.	1 033	1 275	2 308	1 345	1 618	2 963	1 445	1 761	3 206	1 585	1 857	3 442
1 P.M.–2 P.M.	1 012	1 480	2 492	1 416	1 969	3 385	1 573	2 015	3 588	1 632	2 353	3 985
2 " 3 "	1 361	1 601	2 962	1 620	1 687	3 307	1 593	1 992	3 585	1 581	2 209	3 790
3 " 4 "	1 662	1 227	2 889	2 109	1 897	4 006	2 098	1 802	3 900	2 820	1 985	4 805
4 " 5 "	2 294	1 061	3 355	4 068	1 843	5 911	4 306	1 564	5 870	4 500	1 827	6 327
5 " 6 "	7 094	1 113	8 207	9 402	1 580	10 982	11 413	2 124	13 537	13 355	2 164	15 519
6 " 7 "	7 187	924	8 111	8 519	1 121	9 640	9 222	1 386	10 608	10 813	1 392	12 205
7 " 8 "	1 921	1 101	3 022	2 251	1 402	3 653	2 244	1 621	3 865	2 548	1 637	4 185
8 " 9 "	915	711	1 626	1 373	652	2 025	1 538	797	2 335	1 447	744	2 191
9 " 10 "	855	598	1 453	1 314	562	1 876	1 305	673	1 978	1 492	651	2 143
10 " 11 "	896	607	1 503	1 271	667	1 938	1 427	884	2 311	1 509	766	2 275
11 " 12 "	838	464	1 302	1 307	480	1 787	1 470	687	2 157	1 306	662	1 968
Total.....	32 146	38 091	70 237	42 716	48 414	91 130	47 185	50 942	98 127	53 044	57 190	110 234
Per cents. each way...	45.8	54.2	100.	46.9	53.1	100.	48.1	51.9	100.	48.1	51.9	100.

four days about 18 and 12 months apart, is given in Table IV. and is for the even hour as noted in the first column. The maximum

number therein recorded carried both ways is 15 519 passengers, and one way is 13 355 passengers, each between 5 and 6 o'clock p.m., Tuesday, October 29, 1889. During the morning and evening rush, when the travel for a short time is greatly concentrated, it may exceed these numbers; thus Monday, November 18, 1887, 12 160 passengers, and about a year later over 14 000 passengers were carried from New York to Brooklyn in the hour from 5.30 to 6.30 o'clock p. m. Doubtless on other days of which there is no record, as on Tuesday, April 30, 1889, above mentioned, a still larger number of passengers per hour was carried.

PROBABLE INCREASE OF TRAFFIC.

9. Referring to the data already given and comparing with the basis of the preliminary estimate of maximum travel over the Bridge Railway, it will be noticed that the daily average number of passengers in September, 1885, was 1.04, and in April, 1889, was 1.75 that carried by Fulton Ferry in February, 1878; that the daily number by record, December 10, 1888, was 1.14, and April 30, 1889, was 1.43 that carried by the five Union Ferries also in February, 1878; that the maximum number carried one way per hour, May 25, 1886, was 1.09 the number estimated to be provided for, and that since this has steadily increased until it has more than doubled.

10. It is difficult to estimate with reasonable certainty what in the future will be the increase of traffic on the Bridge Railway. Travel between two points usually will move over the easiest connecting lines, as determined by the speed, regularity and frequency of the transit and the comfort and cheapness of the service. If, for instance, these points are the home of a passenger in Brooklyn and his place of business in New York, generally whether he will travel on the Bridge Railway will depend somewhat on other railway lines connecting with the latter; various similar independent conditions, separately or together will promote or retard an increase of traffic.

11. In Brooklyn, new districts are being built up and the old are becoming more densely populated; means of communication are multiplying and being improved; all of which at present tend to increase the number of passengers to be carried by the Bridge Railway, probably however in diminishing ratios; for on the other hand, the lower part of New York, with which the Bridge connects, is nearly full and the overflow is rapidly northward. Were the transit as easy, many residents of Brooklyn engaged in New York,

daily passengers on the Bridge Railway, would now cross the East River at the foot of Broadway, on shorter and more direct lines between their homes and business, thereby saving time and reducing expense; and the relative number of such will increase as Brooklyn extends eastward and northward.

12. Taking the number of passengers carried annually the five years beginning March 1, 1885, and given in Table I. as a basis, and assuming that the yearly increase in the past therein exhibited, establishes a uniform law for the future, the second column of Table V. was computed; its probable value is to su

TABLE V.—ESTIMATE OF TRAVEL EVERY FIFTH YEAR FOR FROM MARCH 1, 1885.

Year beginning March 1.	Total number of passengers for the year.	Maximum number of	
		Any day during the year.	An
1890	37 000 000	169 000	
1895	44 250 000	202 000	
1900	49 300 000	225 000	
1905	53 250 000	243 000	
1910	56 600 000	259 000	
1915	59 500 000	272 000	
1920	62 050 000	284 000	
1925	64 350 000	294 000	
1930	66 450 000	304 000	
1935	68 400 000	313 000	

degree what the traffic over the Bridge Railway ma as is very improbable, the governing conditions remai The second and third columns of the Table are simila the record for these past years.

TRAIN SERVICE.

13. Since the Bridge Railway was first operated, of trains over it run daily and of cars in each train increased, these being changed as need be to accor fluctuating traffic offered, which varies with the occa weather, as well as the time of day, the day of the season. The first train of one car ran over the Railw 1883; the following day five trips were made and pas first taken September 24. Two-car trains were run Octo 1883, three-car trains September 15, 1885, and four-car trains September

9, 1888. Trains were first run during the busy hours morning and evening, on 1½ minutes headway March 5, 1885, and on 1⅓ minutes headway March 2, 1886. Experimentally, 3 three-car and 10 two-car trains were run on 1¼ minutes headway, 1¼ hours in the morning and 2 hours in the evening, September 27, 1886. Usually however, the minimum headway during the day's run is 1½ minutes.

14. Table VI., compiled from the Train Dispatcher's daily record, giving the number, order and headway of trains sent out from Brooklyn Station during the days mentioned, exhibits fairly the operation of the Railway; the last, April 30, 1889, being that on

TABLE VI.—NUMBER AND HEADWAY OF TRAINS.

Tuesday, April 29, 1884. From 5 A.M. to 12:50 A.M. 19 hours 50 min.			Tuesday, April 22, 1886. From 12 A.M. to 12 A.M. 24 hours.			Tuesday, May 1, 1888. From 12 A.M. to 12 A.M. 24 hours.			Tuesday, April 23, 1889. From 12 A.M. to 12 A.M. 24 hours.			Tuesday, April 30, 1889. From 12 A.M. to 12 A.M. 24 hours.		
Number of trains.	Number of cars in train.	Headway, minutes.	Number of trains.	Number of cars in train.	Headway, minutes.	Number of trains.	Number of cars in train.	Headway, minutes.	Number of trains.	Number of cars in train.	Headway, minutes.	Number of trains.	Number of cars in train.	Headway, minutes.
13	1	5	12	1	4	12	2	4	12	2	4	11	3	4
15	"	4	17	"	15	9	"	15	17	"	15	34	2	7½
5	2	3	16	"	4	8	1	"	15	"	4	20	"	4
6	"	2½	9	2	3	16	2	4	12	4	3	23	4	3
53	"	2	94	"	1½	9	3	3	120	"	1½	35	"	1¾
6	"	2½	46	3	"	140	"	1½	20	"	3	101	"	1½
10	"	3	24	"	2½	138	"	3	87	3	"	15	"	2
7	"	4	18	2	"	72	"	1½	35	4	"	93	"	2¼
54	"	5	90	"	3	18	"	3	70	"	1½	150	"	1½
15	"	4	73	"	1½	10	"	4	10	"	3	45	"	3
20	"	3	37	3	"	55	2	"	7	"	4	45	"	4
32	"	2½	20	2	3				10	3	"			
27	1	3	53	"	4				58	2	"			
20	"	4	6	1	"									
46	"	5												
329 trains, 537 cars.			515 trains, 1 092 cars.			487 trains, 1 358 cars.			473 trains. 1 591 cars.			572 trains. 2 169 cars.		

which the greatest number of passengers, 159 259, so far carried in one day were taken. It is to be noticed that the same trains were also sent out and in the same order from New York Station.

PAST AND PRESENT FACILITIES.

15. On a double line of railway, like that on the Bridge over which the trains are moved by a cable hauled continuously in one direction; with forked switches at the ends of the line whereby the trains are transferred from one main line to the other by locomotives; the passengers entering the cars from one platform and leaving the cars by another platform, each at the two terminal stations; the possible number of trains dispatched in a given period or the reduction of headway between trains, is limited by the time required at the switch to move them from the incoming to the outgoing platform as well as by the time spent in discharging and receiving passengers. The latter, as also the comfort and convenience of those traveling over the Railway, depend much upon the width and area of the station platforms and the width, location and number of the passages and stairways to and from the platforms.

16. Since the Railway was first operated, the transfer switches have from time to time been extended and improved. Originally in New York Station each of the two platforms was 8 feet 9 inches wide and with a stairway of the same width; and in Brooklyn Station each platform was 10 feet 6 inches wide and with a stairway 6 feet 6 inches wide. As the traffic increased and more cars in a train were run, additions in length and width were made; now in New York Station each platform is practically 14 feet 9 inches wide and with stairways of a total width of 16 feet 6 inches; also at the westerly end of the causeway over Park Row and Centre Street are two stairways each 8 feet wide, used by passengers to and from the trains over the Bridge Railway and the City Hall branch of the Elevated Railroad. Similarly in Brooklyn Station, now each platform is practically 16 feet 6 inches wide, with stairways and connecting passages of a total width of 25 feet 6 inches for outgoing passengers and of 27 feet 3 inches for incoming passengers.

17. With the present facilities for hauling trains, the capacity of the Railway to carry passengers can be increased only by running more four-car trains and by lessening the headway between them. The least recorded in Table VI. is $1\frac{1}{2}$ minutes; if this is reduced to $1\frac{1}{3}$ minutes, one-fifth more trains may be run in the same time

or 180 cars per hour, and with the transfer switches and the platforms as now arranged, trains cannot with certainty be handled at the Stations in less time.

MAXIMUM CAPACITY.

18. To determine the maximum number of cars that may be dispatched over a single main line in each direction, irrespective of the time spent at the Stations in stops or in transferring the trains from one main to the other; let the length of a car $= l$, the space between adjacent running trains $= h$, and their speed of movement per minute $= v$, all in feet, and the number of cars in a train $= n$; then the length of a train $= ln$, and the space from the front of a train to the front of the train next following $= ln + h$. The headway of trains, in minutes,

$$H = \frac{ln + h}{v}; \qquad [1]$$

and the number of cars dispatched per hour,

$$N = \frac{60\, nv}{ln + h}. \qquad [2]$$

On the Bridge Railway the speed of the cable is 10 miles per hour and the cars are generally about 50 feet in length between coupling pins, hence $v = 880$ and $l = 50$ feet. Assuming that trains will not be run with space between them less than a train length, then for the maximum number of cars which may be dispatched per hour, $h = ln$, the minimum headway $H = \frac{n}{8.8}$ and the number of cars, $N = 528$; whence under the assumption, 528 cars may be sent out per hour or 132 trains of four cars each; the number of cars dispatched being independent of the number of cars in the train.

19. To fully determine the maximum number of cars which may be run on a railway like that over the Bridge, it is necessary also to consider the effect on the headway, of stopping and starting the trains at the station platforms or on the transfer switches. Thus for a train, which in time $= T$ in seconds, over a space $= S$ in feet, with uniformly accelerated or retarded speed, starts from rest and takes a constant velocity, $= V$ in feet per second, or contrariwise, from movement at such constant velocity, is brought to rest,

$$T = 2\frac{S}{V}; \qquad [3]$$

and for any space s, less than S, the corresponding time,

$$t = \frac{2}{V}(Ss)^{\frac{1}{2}}. \qquad [4]$$

For two trains, of n number of cars, each l in feet long, whence of train length $= ln$, running on one track, one starting from and the other stopping at the same platform, with as before, uniformly accelerated or retarded speed, the least possible headway in seconds between them, that the incoming train may not overtake the outgoing one, is,

if ln is less than $2S$; $\qquad H = \frac{4}{V}\left(\frac{Sln}{2}\right)^{\frac{1}{2}}; \qquad [5]$

and if ln is greater than $2S$; $\qquad H = \frac{2S + ln}{V}. \qquad [6]$

If it be assumed, as is reasonable that the space in S which a train starts or stops is in proportion to its length, then for S may be written, aln and the above give, $\qquad H = \frac{4}{V} ln \left(\frac{a}{2}\right)^{\frac{1}{2}}; \qquad [7]$

or $\qquad H = \frac{2a + 1}{V} ln; \qquad [8]$

that is, the minimum headway between trains stopping and starting regularly at a platform or elsewhere, varies directly with the length of the train or the number of cars in it; and as before, the maximum number of cars that may be dispatched is independent of the number of cars in the train.

20. By this examination it appears that if the tracks, platforms and transfer switches or loops of the Bridge Railway permitted, 528 cars may be run per hour; that is 132 trains of four cars each, on a headway of $27\frac{3}{11}$ seconds and with a space between adjacent trains on the main lines of 200 feet. As previously stated: *first*, three-car trains have been run on $1\frac{1}{4}$ minutes headway, whence 144 cars or 48 trains were dispatched per hour; *second*, four-car trains are now run on $1\frac{1}{2}$ minutes headway, whence 160 cars or 40 trains are dispatched per hour; and *third*, as the platforms and switches are now arranged, four-car trains may possibly be run on $1\frac{1}{3}$ minutes headway, whence 180 cars or 45 trains may be dispatched per hour. Comparing these statements of the past and present running of trains with that of the maximum capacity of the Railway as estimated above, the latter is $3\frac{2}{3}$ greater than the *first*, $3\frac{1}{3}$ greater than the *second*, and $2\frac{14}{15}$ greater than the *third*.

21. Dividing the minimum headway now on the Railway—$1\frac{1}{2}$ minutes—into three parts: at the Station the train is emptied,

shifted from one main line to the other, and loaded, each in about 30 seconds. With a suitable arrangement of platforms and transfer tracks, 40 seconds may be taken as the minimum time a train may stop to discharge or receive passengers, without undue crowding or haste; also 25 seconds as the minimum safe headway on the main lines, whereby four-car trains will be separated by a space of $166\frac{2}{3}$ feet. There are 40 seats in each car and by filling the main aisle 100 passengers may be carried without crowding. From this data, the number of passengers which may be transported over the Railway, in trains running on headways varying from 25 seconds to $1\frac{1}{2}$ minutes, as given in Table VII., was computed.

TABLE VII.—CAPACITY OF A DOUBLE LINE OF RAILWAY, CARRYING IN FOUR-CAR TRAINS, WITH ALL SEATED 40, AND WITH SEATS AND AISLES FILLED, 100 PASSENGERS PER CAR.

On main line.		Time that trains remain at platforms.	Number of trains dispatched.		Number of passengers carried.				Capacity compared with four car trains running on 1½ minutes headway.
					Per minute.		Per hour.		
Headway of trains.	Space between trains.		Per minute.	Per hour.	Seats filled.	Seats and aisles filled.	Seats filled.	Seats and aisles filled.	
Min. sec.	Feet.	Min. sec.							
0—25	$166\frac{2}{3}$	0—50	$2\frac{2}{5}$	144	384	960	23 040	57 000	$3\frac{3}{8}$
0—30	240	1— 0	2	120	320	800	19 200	48 000	3
0—35	$313\frac{1}{3}$	1—10	$1\frac{5}{7}$	$102\frac{6}{7}$	274	685	16 457	41 142	$2\frac{4}{7}$
0—40	$386\frac{2}{3}$	1—20	$1\frac{1}{2}$	90	240	600	14 400	36 000	$2\frac{1}{4}$
0—45	460	1—30	$1\frac{1}{3}$	80	213	533	12 800	32 000	2
0—50	$533\frac{1}{3}$	1—40	$1\frac{1}{5}$	72	192	480	11 520	28 800	$1\frac{4}{5}$
0—55	$606\frac{2}{3}$	1—50	$1\frac{1}{11}$	$65\frac{5}{11}$	174	436	10 472	26 181	$1\frac{7}{11}$
1— 0	680	2— 0	1	60	160	400	9 600	24 000	$1\frac{1}{2}$
1— 5	$753\frac{1}{3}$	2—10	$\frac{12}{13}$	$55\frac{5}{13}$	147	369	8 861	22 154	$1\frac{5}{13}$
1—10	$826\frac{2}{3}$	2—20	$\frac{6}{7}$	$51\frac{3}{7}$	137	343	8 228	20 571	$1\frac{3}{7}$
1—15	900	2—30	$\frac{4}{5}$	48	128	320	7 680	19 200	$1\frac{1}{5}$
1—20	$973\frac{1}{3}$	2—40	$\frac{3}{4}$	45	120	300	7 200	18 000	$1\frac{1}{8}$
1—25	$1\,046\frac{2}{3}$	2—50	$\frac{12}{17}$	$42\frac{6}{7}$	112	282	6 776	16 941	$1\frac{1}{17}$
1—30	1 120	3— 0	$\frac{2}{3}$	40	106	266	6 400	16 000	1

22. Table VIII. shows the maximum number of passengers per hour carried either way on the Railway on two days: *first*, on

Tuesday, October 29, 1889 (the last on which the number hourly was counted), the total number carried both ways that day being 110 234; and *second*, on a future day in 1935, as estimated, Table V; the maximum number to be carried on any day in that year being 313 000 and either way any hour in the day 39 000, and for other hours proportionate to the corresponding number on October 29, 1889; also the number of cars and of four car trains required per hour to convey these passengers, if there were, in one case not more than 40 passengers in a car, or one per seat; and in the other case, not more than 100 passengers in a car, or so many as could comfortably occupy the seats and aisles; and lastly the corresponding headways for these trains.

23. By this Table, it appears that during the entire 24 hours, with 40 passengers in a car, only from 7 to 9 o'clock a. m. and from 5 to 7 o'clock p. m. are the train headways, the first day less than now during the busy hours, that is 1½ minutes; and with the trains running on this headway there would have been on these several hours, but from 68 to 84 passengers per car. Similarly for the second day, except on these hours, the headways are not less than 35 seconds; and with the trains running on 30 seconds headway, there would be on the several busy hours but from 66 to 82 passengers per car. Therefore it follows in each case, that if there were means provided to admit to the outgoing platform at one time not more than a train load of passengers, others in order of arrival at the Station being held back, in a waiting-room large enough for the purpose and having easy and abundant communication with the platform, until the next outgoing train was ready; generally each passenger would have a seat, and even when the throng was greatest no one would be detained longer than one headway, and all crowding on the platforms would be avoided.

24. A consideration of Table VIII. also raises the doubt, whether hereafter it will be expedient to attempt to provide a seat for each passenger during the whole day, without regard to the sudden and brief increase in numbers to be carried, peculiar to the morning and evening hours. Taking per car, 100 as the most who can be conveniently transported, and 40 as those who can be seated, the operating expenses thereby would be increased greatly in the ratio of these numbers, without much equivalent benefit. As bearing upon this question, reference is made to a calculation of the average weight per month actually hauled for each passenger, since

TABLE VIII.—MAXIMUM NUMBER OF PASSENGERS PER HOUR CARRIED EITHER WAY, THE LEAST NUMBER OF CARS AND OF TRAINS REQUIRED AND THEIR HEADWAYS.

Hour beginning at	110 234 passengers carried both ways on Tuesday, October 29, 1889.							313 000 passengers carried both ways per day.						
	Number of passengers, per count.	40 passengers in a car.			100 passengers in a car.			Number of passengers, estimated.	40 passengers in a car.			100 passengers in a car.		
		Number of car loads.	Number of 4-car trains.	Headway.	Number of car loads.	Number of 4-car trains.	Headway.		Number of car loads.	Number of 4-car trains.	Headway.	Number of car loads.	Number of 4-car trains.	Headway.
				M. S.			M. S.				M. S.			M. S.
12 P.M.	615	16	4	15— 0	7	2	30— 0	1 796	45	12	5— 0	18	5	12— 0
1 A.M.	295	8	2	30— 0	3	1	60— 0	862	22	6	10— 0	9	3	20— 0
2 "	242	7	"	" "	"	"	" "	707	18	5	12— 0	8	2	30— 0
3 "	178	5	"	" "	2	"	" "	520	13	4	15— 0	6	"	" "
4 "	146	4	1	60— 0	"	"	" "	427	11	3	20— 0	5	"	" "
5 "	610	16	4	15— 0	7	2	30— 0	1 782	45	12	5— 0	18	5	12— 0
6 "	3 780	95	24	2—30	38	10	6— 0	11 038	276	69	0—52	111	28	2— 8
7 "	11 836	206	74	0—48	119	30	2— 0	35 562	890	223	0—16	356	89	0—40
8 "	11 255	282	71	0—50	113	29	2— 4	32 865	822	206	0—17	329	83	0—43
9 "	5 507	138	35	1—42	56	14	4—17	16 081	403	101	0—35	161	41	1—27
10 "	3 079	77	20	3— 0	31	8	7—30	8 991	225	57	1— 3	90	23	2—36
11 "	2 205	56	14	4—17	23	6	10— 0	6 439	161	41	1—27	65	17	3—31
12 M.	1 857	47	12	5— 0	19	5	12— 0	5 423	136	34	1—45	55	14	4—17
1 P.M.	2 353	59	15	4— 0	24	6	10— 0	6 871	172	43	1—23	69	18	3—20
2 "	2 209	56	14	4—17	23	"	" "	6 451	162	41	1—27	65	17	3—31
3 "	2 820	71	18	3—20	29	8	7—30	8 235	206	52	1— 9	83	21	2—51
4 "	4 500	113	29	2— 4	45	12	5— 0	13 140	329	83	0—43	132	33	1—49
5 "	13 355	334	84	0—42	134	34	1—45	39 000	975	244	0—14	390	98	0—36
6 "	10 813	271	68	0—52	109	28	2— 8	31 574	790	198	0—18	316	79	0—45
7 "	2 548	64	16	3—45	26	7	8—34	7 441	187	47	1—16	75	19	3— 9
8 "	1 447	37	10	6— 0	15	4	15— 0	4 226	106	27	2—13	43	11	5—27
9 "	1 492	38	"	" "	"	"	" "	4 357	109	28	2— 8	44	"	" "
10 "	1 509	"	"	" "	16	"	" "	4 407	111	"	" "	45	12	5— 0
11 "	1 306	33	9	6—40	14	"	" "	3 814	96	24	2—30	39	10	6— 0

and including April, 1884; from which it appears that this weight ranges from 749 pounds in March, 1885, to 1250 pounds in April,

1889; or from 5 to 9 pounds of dead weight to 1 pound of live weight transported, an increase of 80 per cent.

25. Referring to the "Typical diagrams of terminal Stations," Figs. 2–6: for a double track railway with an incoming and an outgoing platform and transfer switches at each terminal, as shown Fig. 2, let the time in which a train runs from A on the incoming track, and comes to rest at the incoming platform, or starting at the outgoing platform reaches B on the outgoing track $= b$; the time it remains at either of the platforms $= p$, or starting from rest, in which it is moved its length $= c$, and the headway between trains on the main lines $= H$, then that an incoming train may not overtake the preceding train at the incoming platform,

$$b + H = \text{or} > b + p + c; \text{ hence } H = \text{or} > p + c. \qquad [9].$$

Let the time in which a train is transferred from one platform to the other $= d$, then if the trains are run one after the other on the switch without stop or interference at crossings, that an outgoing train may not overtake a preceding one at the outgoing platform,

$$b + p + H + d = \text{or} > b + p + c + d;$$

hence as before, $\qquad H = \text{or} > p + c.$

26. If however, the main tracks are each divided at the Stations into two or more branches, with a platform for each branch, as shown Figs. 3, 4 and 5, thus forming a system of incoming and outgoing slips, and the trains are run into and out from these slips in numerical order, there will be as many headways between two adjacent trains entering or leaving a slip, as there are branches of each main line or pairs of slips. If as before, the trains are transferred from the incoming to the outgoing slips without stop or interference one with another, that a train may not overtake a preceding one at a platform, for a double system of slips, as shown Figs. 3 and 4,

$$2H = \text{or} > p + c; \text{ hence } H = \text{or} > \frac{p + c}{2}; \qquad [10]$$

and for a triple system of slips, as shown Fig. 5,

$$3H = \text{or} > p + c; \text{ hence } H = \text{or} > \frac{p + c}{3}; \qquad [11]$$

therefore, as $p + c$, the total time a train, first remains at a platform to discharge or receive passengers, and then starting from rest it is moved its length (which cannot fall below a certain limit) it appears that for a fixed value of this limit, the headway between adjacent trains on the main line, so far as platform arrangements

are to be considered, may be reduced as the number of slips is increased.

27. The condition named above, that the trains shall be moved from the incoming to the outgoing platform without stop or interference, one with another, does not obtain where the transfer is made over switches, as shown Figs. 2, 3 and 4, since to surely prevent collision, *first*, if but one switch is used a train must not leave the incoming platform until the preceding train has passed the clearance point at F, and *second*, if two switches are used also a train must not leave the end of the switch D until the following train has passed the clearance point at E. In the first case, let the time in which a train starting from rest at the incoming platform is run out on the switch and back past the clearance point at F be e; then that a train from the incoming platform may clear the preceding train,

$$b + p + H = b + p + e; \text{ hence } H = e; \quad [12]$$

also,

$$e = \text{or} > p + c; \quad [13]$$

whence with but one transfer switch in use, the headway between trains on the main lines cannot be less than the time in which a train starting from rest at the incoming platform passes the clearance point at F, nor can this be reduced below a certain limit.

28. In the second case, the general solution as applied to a double slip and switch system, is more complex. Referring to Figs. 3 and 4, and designating the trains which run on the A tracks and switch by A, and those on the B tracks and switch by B; let the times respectively the A and B trains remain, at the incoming platforms be p and P, at the switches be w and W, and at the outgoing platforms be q and Q; the time in which a train runs from the incoming platform out on its switch or from its switch back to the outgoing platform be f; the time in which when running in from the switch it clears the spur at F be g, and when running out to the switch, it clears the crossing at E be G; also as before, let the headway between trains on the main line be h.

First.—If the transfer is made by locomotives alone, that the A locomotive may haul its train out:

$$2h + p = p + w + 2f; \quad [14]$$

that the B locomotive may haul its train out:

$$3h + P = h + P + W + 2f; \quad [15]$$

that the B train in running out from the incoming platform

may clear the crossing before the preceding A train leaves its switch:

$$h + P + g = p + w + f; \qquad [16]$$

and since the trains must arrive at and depart from the station at headway intervals:

$$p + q + w + 2f = P + q + W + 2f; \qquad [17]$$

whence, combining these equations:

$$h = \frac{w + 2f}{2} = \frac{W + 2f}{2}; \text{ and } w = W; \qquad [18]$$

also,

$$h = p - P + w + f - g; \qquad [19]$$

and

$$p - P = Q - q. \qquad [20]$$

From this it appears that the headway h is equal to one-half the time $w + 2f$, in which the transfer from the incoming to the outgoing platform is made; also to the sum of the difference in times $p-P$, a train remains at the two platforms, the time w, it remains on its switch and the time, $f-g$, in which it runs from the crossing to the switch. Again for a given headway h; the time, w, a train must remain on its switch and the difference in times, $p-P$, it must remain at its platforms, have a fixed value; and as h is increased, $\frac{w}{2}$ will increase and $p-P$ will decrease the same quantity.

Second.—If the transfer is made by cable and locomotive, that a train may leave the incoming platform, when the preceding train has cleared the spur, equations *14* and *15* become:

$$2h + p = p + w + f + G; \qquad [21]$$

$$3h + P = h + P + W + G; \qquad [22]$$

and equations *16* and *17* are unchanged; whence, as before,

$$h = \frac{w + f + G}{2} = \frac{W + f + G}{2}; \text{ and } w = W; \qquad [23]$$

that is: the headway h is equal to half the time $w + f + G$, in which the transfer from the incoming platform to and from the switch and past the crossing is made; other deductions are as for the *first*.

Assuming that a train is not started to or from its switch until its track is clear, and that starting from rest it is moved at full speed or moving at full speed it is brought to rest in two-thirds its length, or for a four-car train in $133\frac{1}{3}$ feet; then f may be taken at 40, g at 34, and G at 26 seconds. Also, that each train coming into the Station may begin to stop if necessary, at a danger point a train

length or 200 feet back from the preceding train on the same track at the incoming platform,

$$h = > \frac{p + R}{2}; \qquad [24]$$

in which R is the time required for the train to run from this point and come to a stop at the platform, or 37 seconds. From this data Table IX. is constructed.

TABLE IX.—SCHEDULE SHOWING THE RUNNING OF FOUR-CAR TRAINS INTO AND OUT OF A STATION WITH DOUBLE SLIPS AND SWITCHES.

Times are in seconds.

FIRST—TRAINS TRANSFERRED BY LOCOMOTIVES ALONE.

Headways = h	40	45	50	55	60	65	70	74
Trains remain on switches = w	0	10	20	30	40	50	60	68
Difference in times, trains remain at platforms = $p-P$	34	29	24	19	14	9	4	0
A trains remain at incoming and B trains at outgoing platform = p	57	64	64	64	64	64	64	64
A trains remain at outgoing and B trains at incoming platform = P	23	35	40	45	50	55	60	64
Platforms are vacant	17	10	10	10	10	10	10	10

SECOND—TRAINS TRANSFERRED BY CABLES AND LOCOMOTIVES.

Head ways = h	33	35	40	45	50	55	60
Trains remain on switches = w	0	4	14	24	34	44	54
Difference in times, trains remain at platforms = $p-P$	27	25	20	15	10	5	0
A trains remain at incoming and B trains at outgoing platform = p	43	47	57	60	60	60	60
A trains remain at outgoing and B trains at incoming platforms = P	16	22	37	45	50	55	60
Platforms are vacant	17	13	3	0	0	0	0

It will be noticed that up to 1 minute and 14 seconds headway for trains transferred by locomotives alone, and up to 1 minute headway for trains transferred by cable and locomotives; they are alternately a longer and shorter time at the incoming platforms and contrariwise at the outgoing platforms; and that with headways greater than these the trains may be at either platform a time equal to the headway. A graphical illustration of this schedule, for trains transferred by cable and locomotives, on from 40 to 60 seconds headway, is given by the diagrams, Figs. 7 and 8.

29. To aid in fixing proper values for the terms in the general equations established above, expressing the several conditions which limit the running of trains as proposed, reference is had to observations made at the two Stations, of the movement of trains during the busy morning and evening hours, recorded in Table X.; also at New York Station, to determine the time in which trains, starting from rest at the outgoing platform were first moved at full speed, recorded in Table XI. In each case the observations were made on several trains running in the usual order; they were operated by the men then assigned to that work, and were performing regular service.

30. Again referring to the "Typical diagrams of terminal Stations," Figs. 2–6, collating and applying the data above given, on a double track railway, the minimum headway between trains on the main lines will be as follows:

First.—With an incoming and outgoing platform and forked transfer switches at each terminal, together constituting a single slip system, as shown Fig. 2, the minimum headway (equation *12*), H equals e, the time in which a train, starting from rest at the incoming platform, is run out on a switch and back past the clearance point. This by computation, assuming that a train thus moved acquires full speed in two-thirds its length or in 133⅓ feet, without allowance for delay at the end of the switch when the movement is reversed, is 1 minute and 6 seconds; by Table X., the mean time at New York Station in which three-car trains were transferred, was 1 minute and 12 seconds, and in which four-car trains were transferred was 1 minute and 22 seconds; whence under the most favorable conditions for handling the trains, this for four-car trains cannot be safely taken less than 1 minute and 20 seconds.

Second. — With double incoming and outgoing tracks, their platforms and double forked transfer switches at each terminal, together constituting a double slip system, as shown Figs. 3 and 4 the minimum headway H, permitting trains to remain not less than 40 seconds (see § 21) at each of the platforms, to discharge and receive passengers, per Table IX., is 45 seconds.

Third.—With, at each terminal, double incoming and outgoing tracks and their platforms as before, and double transfer loops (as shown for a triple slip system, Fig. 5) whereby the trains may be moved from one platform to the other without stop or interference, also together constituting a double slip system, the minimum headway (equation *10*), H, is not less than one-half the sum of p, the

TABLE X.—ARRIVAL AND DEPARTURE OF TRAINS AT AND FROM THE STATIONS.

THREE-CAR TRAINS. MONDAY, NOVEMBER 21, 1887.

Brooklyn Station, beginning at 7h. 12m. 23s. A.M								New York Station, begin'g at 5h. 7m. 20s. P.M.							
Number of trains.	Mean headway of trains on the main line.	Number of trains.	Mean time in which passengers were discharged a: the incoming platform.	Number of trains.	Mean time in which trains were transferred from one main line to the other.	Number of trains.	Mean time in which passengers were received at the outgoing platform.	Number of trains.	Mean headway of trains on the main line.	Number of trains.	Mean time in which passengers were discharged at the incoming platform.	Number of trains.	Mean time in which trains were transferred from one main line to the other.	Number of trains.	Mean time in which passengers were received at the outgoing platform.
	Min. sec.		Sec.		Min. sec.		Sec.		Min. sec		Sec.		Min. sec.		Sec.
6	1—29.5	8	30.3	7	1—45.4	7	42.6	6	1—29.5	6	34.6	6	1—16.8	6	41.1
37	1—29.8	37	30.9	36	1—41.4	37	44.5	36	1—30.2	37	19.7	37	1—11.1	37	43.3
43	1—29.8	45	30.8	43	1—42.1	44	44.2	42	1—30.1	43	21.3	43	1—11.9	43	42.9

FOUR-CAR TRAINS. FRIDAY, OCTOBER 25, 1889.

New York Station, beginning at 5 o'clock, P.M. Headways 1m. 30s.

Number of trains.	Time in which passengers were discharged on the incoming platform.	Number of trains.	Time in which train was moved from the incoming platform to the switch.	Number of trains.	Time that train stood on the switch.	Number of trains.	Time in which train was moved from the switch to the outgoing platform.	Number of trains	Time in which passengers were received at the outgoing platform.	Number of trains.	Total time between arrival and departure of train at and from the Station.
	Sec.		Sec.		Sec		Sec.		Sec.		Min. Sec.
1	20	2	45	1	15	1	27	1	31	1	2—41
"	22	4	46	"	16	"	29	"	34	"	2—43
"	24	2	47	3	17	3	30	"	35	"	2—44
2	28	6	48	1	18	2	32	"	37	"	2—47
1	29	3	50	"	19	5	33	"	38	"	2—48
3	30	1	52	"	20	1	34	2	39	"	2—50
1	31	"	55	2	21	5	35	5	40	"	2—52
3	32	"	63	1	22	1	36	2	41	"	2—53
2	33			3	23	"	37	1	42	"	2—56
"	36			2	25			2	44	"	2—57
1	38			1	27			1	48	"	2—58
"	42			"	29			2	50	"	2—59
"	43			"	30					"	3— 0
				"	39					"	3— 1
										"	3— 2
										3	3— 3
										1	3— 8
										"	3—14
20	31.5	20	48.8	20	22.4	20	32.9	20	40.7	20	2—56.1

time a train remains at a platform, and of c, the time in which the train on departure is moved its length. By computation, assuming as before that a train acquires full speed in two-thirds its length or 133⅓ feet, this last is 23 seconds, which fairly agrees with the observations recorded, Table XI.; whence the minimum headway may be taken at 32 seconds.

TABLE XI.—TIMES IN WHICH TRAINS WERE MOVED FROM REST TO CABLE SPEED AT OUTGOING PLATFORM, NEW YORK STATION; THE LENGTHS OF CABLE THAT PASSED THE STARTING POINT, AND THE SPACES OVER WHICH THE TRAINS MOVED IN SUCH TIMES.

Date.	Hour.	Number of cars in train.	Time of movement observed.	Length of cable which passed the starting point. Computed.	Space over which the train moved. Computed.	Number of passengers. Estimated.	Weather.
1887.			Seconds	Feet.	Feet.		
May 30	10— 0 A.M.	3	11.3	165	82.3	60	Dry.
	11— 0 "	"	"	"	"	"	"
June 1	10—20 "	"	12.5	183.3	91.7	"	Wet.
	10—50 "	"	18.3	268.4	134.2	"	"
	11— 5 "	"	18	264	132	"	"
	11—25 "	"	15.1	221.5	110.8	"	"
	5—10 P.M.	"	13.4	196.5	98.3	120	Dry.
	5—30 "	"	15.3	223.7	111.9	200	"
	5—50 "	"	16	234.7	117.4	350	"
	6—10 "	"	16.3	238.4	119.2	"	"
June 2	8—40 A.M.	"	12.5	183.3	91.7	60	"
Mean of eleven trials.			14.5	213.1	106.2		
1889. December 31	4—54 P.M. to 6— 3 P.M.	4	12	176	88	120	Dry.
		"	10	146.7	73.3	185	"
		"	11	161.4	80.7	250	"
		"	13	190.7	95.3	315	"
		"	10	146.7	73.3	385	"
		"	12.5	183.3	91.7	450	"
Mean of six trials.			11.4	167.5	83.8		

Fourth. — With triple incoming and outgoing tracks, their platforms and triple transfer loops at each terminal, together constituting a triple slip system, as shown Fig. 5, the minimum headway (equation *11*) H, is not less than one-third the sum of p and c, or 21 seconds. This is not so great as the minimum headway between trains on the main lines, heretofore taken (§ 21) at 25 seconds; hence by this system the maximum capacity of the Railway is reached.

In Table XII. these headways and the number of trains and cars which may be run thereon, are collected and compared with headways and trains as at the present time.

TABLE XII.—MAXIMUM CAPACITY OF A PAIR OF MAIN LINES OF RAILWAY, AS LIMITED BY DIFFERENT TERMINAL ARRANGEMENTS.

Terminal Arrangements.	Minimum headways.	Number per hour dispatched.		Capacity compared with 4-car trains running on 1½ minutes headway.
		Of 4-car trains.	Of cars.	
	Min. sec.			
Single slip system with forked switches, as now operated—Fig. 1	1—30	40	160	1
First—Single slip system with forked switches, operated to maximum capacity—Fig. 1	1—20	45	180	1⅛
Second—Double slip system with forked switches —Figs. 2 and 3	0—45	80	320	2
Third—Double slip system with loops—Fig. 4	0—32	112½	450	2 13/16
Fourth—Triple slip system with loops, as limited by capacity of the main lines—Fig. 4	0—25	144	576	3⅗

CONDITIONS TO BE OBSERVED.

31. The principles here established determine the conditions limiting the maximum traffic capacity of the Bridge Railway. A complete system of transit for this traffic, would permit a ready increase or decrease of trains during each day to meet the fluctuating demand, a consequent change of headway on the main lines without reduction of the time at the platforms sufficient to allow easy delivery and reception of passengers; together with abundant car and platform space, free passage from and to the trains, spacious waiting rooms, sure and regular train service, and the greatest possible safety

to passengers and train men. All the working parts should be capable of regular and continuous operation, and so arranged that when renewal or repair of any portion of the plant is necessary, such may be done, without interference with the movement of trains, or unduly limiting the transit of passengers.

32. In providing the necessary station arrangements to effect this, certain conditions govern. The two main lines of Railway, their branches at the platforms and the transfer switches or loops at the terminals, together form a complete circuit, over which the trains will run continuously in one direction. If at the Stations, there are more than a pair of platforms, one for incoming and one for outgoing passengers, the others must be within the circuit, and access to them from the street or connecting railways can be had only by passages under or over the tracks; that is from a lower or a higher level. The platforms should be of a width sufficient to permit the movement of the most compact column of people allowed thereon, at a safe distance from the platform margins, from and to the trains, without crowding or undue haste, and the connecting stairways should be ample in number and capacity to freely deliver this column. The stairways, platforms and car openings, which together form a path over which passengers move between the train and beyond the Station, should be so arranged that on this path the entire current will be without interruption and in one direction. To prevent crowding on the outgoing platforms, in the busy morning and evening hours when the maximum traffic of the day is offered, or when from any cause there is a delay in the running of the trains and an accumulation of passengers; there should be commodious waiting rooms, one on a lower level for passengers from the street, and one on a higher level for passengers from connecting railways; and means should be taken to regulate the flow therefrom, so that not more than a train load will be on the outgoing platform at one time, and that entrance to this platform be in the order of arrival at the waiting room; whereby even when the travel is greatest, no one need be detained longer than a single headway. To reduce the cost of the sale and collection of tickets to a minimum, there should be in each Station but two of these waiting rooms, each with one booth from which tickets are sold. What may be done in this particular appears from the following: at present it costs to sell to and collect tickets from the Railway passengers, in Brooklyn Station at the separate passages connecting the Brooklyn Elevated Railroads, one

for each, and the fourth passage leading from the street, $66 per day of 24 hours or $24 090 per year; and in New York Station, at the two passages, one on the Railway and the other on the street level, $45.38 per day or $16 561.88 per year; that is, because of the difference in the arrangements for the reception of passengers at the two Stations, it costs for practically a like service, $20.62 per day or $7 528.12 per year less at New York than at Brooklyn Station, or 4 per cent. on a permanent investment of $188 200.

IMPROVEMENTS REQUIRED.

33. So far on the Bridge Railway, except for a few months at New York Station, after it was first opened to public use, the trains have been transferred at the terminals, from one main line to the other by locomotives kept for this purpose, also to haul the trains as required to and from the storage yard and over the Railway during the early morning hours when the travel is light, and occasionally at other times, when from derailment, failure of a part of the machinery or other cause, the cable driving plant is briefly stopped. In New York Station the outgoing trains while receiving passengers take hold of the cable at the platform; at Brooklyn Station they are by locomotive pushed out from the platform on to the main track before the cable grips are applied. It is desirable that the trains should be hauled by cable over the main lines during the entire 24 hours; and whenever in the future they are dispatched on much less headway and a greater number are put into service than now, it will be necessary because of the limited time in which such may be done, to make the transfer at the terminal stations from one main line to the other also by cable; which may be done and thereby the daily cost of motive power be greatly reduced. As bearing on this, Table XIII. is given, which shows for each of the three years ending May 31, 1889, the number of miles a single car was hauled by cable and by locomotives, including the transfers at the terminals; and the cost of each service. From this will be seen, that in these years the work done by the locomotives was but 13 per cent. of the whole, and at over 56 per cent. of the total cost; that is, to perform the same service, it costs 8½ times as much if done by locomotives than if done by cable. A reduction of this annual amount about two-thirds or $30,000, is four per cent. on an investment of $750,000; hence a large permanent expenditure to materially lessen it will be wise.

TABLE XIII.—SERVICE AND COST OF MOTIVE POWER.

Year ending May 31.	Car miles, including switches. By cable. Number of miles a single car was hauled.	Car miles. By cable. Per cent. of total.	Car miles. By locomotives. Number of miles a single car was hauled.	Car miles. By locomotives. Per cent. of total.	Car miles. Total number of miles a single car was hauled.	Cost of motive power. By cable. Cost of service.*	Cost of motive power. By cable. Per cent. of total.	Cost of motive power. By locomotives. Cost of service.	Cost of motive power. By locomotives. Per cent. of total.	Cost of motive power. Total cost of service.	Cost of motive power. Per car mile. By cable.	Cost of motive power. Per car mile. By locomotive.	Proportionate cost by locomotives, that by cable being one.
						Dollars.		Dollars.		Dollars.	Cts.	Cts.	
1887	804 317	87.3	116 907	12.7	921 278	28 634.39	40.7	41 797.58	59.3	70 431.97	3.56	35.75	10.04
1888	894 851	86.7	136 978	13.3	1 031 829	30 094.48†	39.4	46 291.02	60.6	76 385.50	3.36	33.79	10.05
1889	1 030 567	86.8	156 076	13.2	1 186 643	44 063.57†	49.5	44 989.22	50.5	89 052.79	4.28	28.83	6.74
For the 3 years.	2 729 789	87.	409 961	13.	3 139 750	102 792.44	43.6	133 077.82	56.4	235 870.26	3.77	32.16	8.54

34. That a double or triple slip system may be operated with the greatest possible efficiency and safety, for each part there should be a separate railway and hauling cable, forming with its main lines on the structure proper, its branches at the stations and transfer switches or loops at the terminals, an entire and independent railway circuit, without a break in the tracks except where the trains are run from and to the storage-yard; special automatic appliances being inserted where the branches separate from or join to the main lines, at the crossings of single tracks. For this, on the Bridge structure, the rails of the double or triple systems on the same side of each track, should be laid quite close together and with a space between them sufficient to allow clearance of the car wheel flanges; the cables should also run side by side, each in the centre of its pair of rails. The grips should permit the trains to be stopped, started

* This includes the cost of steam made by the boilers of the cable driving plant, used to drive the electric lighting plant daily (less $200 per month deducted therefor), the shop's engine each working day, and for heating the office building and Brooklyn Station during the cold season.

† These also include the cost of steam used in a series of trials of the new cable driving plant before it was put into regular service.

or run slower or faster than the cable, without dropping it. This arrangement of tracks and cables will allow whole or part of the system to be operated as the traffic offering may demand, and in case a single part becomes disabled from any cause, the remaining one-half or two-thirds of the system may still be used as before.

35. From the position on the Bridge structure of the two main lines of railway, between the roadways on the outside and the footway in the centre, as these are now continued outward past the Stations to the City streets; at each terminal a large number of railway passengers to and from the streets and all of the foot passengers must necessarily cross the entrance or exit of a roadway, always with discomfort and at times attended by great danger. A terminal station for the Bridge, freely located, should be in an open square, surrounded on every side by broad streets and beyond where the roadways enter or leave the structure; access to the station could then be had with equal facility from either direction, and the concentrated traffic on the roadways would no longer be a menace to passengers over the railway or footway.

PLANS HERETOFORE ADOPTED.

36. From time to time, as occasion served, since the Bridge Railway was first operated, the improvement of its traffic facilities has been considered by the Engineers in charge. In a communication to C. C. Martin, Chief Engineer and Superintendent, from the writer, dated September 28, 1887, this problem was discussed: "How to design stations at the ends of a double track railway, so "that any probable number of passengers may be carried, without "undue crowding in the waiting rooms and passages, on the plat-"forms or in the cars, with the least possibility of delay in transit "and with the greatest safety." The plans therein presented, applied to the Bridge Railway, involved the sacrifice of existing structures, the acquirement of largely increased areas for new station sites and the erection of entirely new station buildings.

37. In view at that time of the consequent expense, the contingent delay and perhaps doubt in securing the necessary authority and funds, as well as the difficulty of managing the traffic while the removals and constructions were being made; in a succeeding communication, dated December 19, 1887, inquiry was made "if the Stations" then "in use" might "possibly be modified to "meet future and increasing demands, as from time to time may

"develop, until the full capacity of the double line of railway over "the Bridge is reached; also keeping in mind the need for easy, "safe, comfortable and certain transit of all who may come, however "great the throng may be;" and in answer to this inquiry, plans for Stations in New York and Brooklyn were presented.

38. At a meeting of the Board of Trustees, April 11, 1887, two Committees were appointed to recommend plans for the improvement of the terminal facilities of the Railway; to one, consisting of Messrs. Howell and Macdonald and afterwards also of Mr. Clarke, was referred that relating to New York Station, and to the other, consisting of Messrs. Thurber, Barnes and Keeney, that relating to Brooklyn Station. These Committees conferred with the Chief Engineer and Superintendent; and the second Committee reported to the Board of Trustees, February 13, 1888, presenting four plans for a Brooklyn Station and recommending one, to be located centrally over Sands Street, which was then adopted. The first Committee employed a Consulting Engineer and referred the plans submitted, to a Board of Experts which reported February 23, 1888; the Committee reported to the Board of Trustees, April 17, 1888, and recommended two plans: "Plan A" for New York Station, to be located on and easterly of the site now occupied, and "Plan B" for Brooklyn Station, in design and location similar to that presented February 23, 1888, and these plans, shown by Figs. 9 and 10, were then adopted. At a meeting of the Board of Trustees, April 8, 1889, a Committee was appointed to recommend plans for the improvement of terminal facilities in New York, consisting of Messrs. Myers, Thurber and Anderson, which reported May 14, 1889, recommending a plan for New York Station, substantially like "Plan A," presented April 17, 1888, but of greater width at the entrance along Park Row, and this was then adopted. At a meeting of the Board of Trustees, September 9, 1889, the following preamble and resolution were presented:

"*Whereas*, The traffic on the New York and Brooklyn Bridge has increased much beyond what was originally estimated and provided for, and doubtless will steadily continue to increase, while the facilities therefor, though from time to time extended, still fall far short of adequately transporting the possible maximum travel over the structure itself; and

"*Whereas*, The Stations now in use are unsuitable in plan and unfitting in architectural design, forming unsymmetrical and inappropriate portals to a grand engineering work; and

"*Whereas*, Plans for improving terminal facilities, including the erec-

tion of new Stations, one in New York and one in Brooklyn, have on the recommendation of three different Committees, been separately adopted by the Trustees;

"*Resolved*, That four Trustees be appointed by the President and constitute with himself as ex-officio member, a Committee on Improved Traffic Facilities of the New York and Brooklyn Bridge, which Committee shall consider the plans and means necessary to provide such facilities for transporting the traffic over the Bridge, as will permit the maximum possible travel on its several lines of communication, the railway, roadways and footway, to be handled with comfort, safety, rapidity, economy and without delay; including designs for the stations required, suitable for the uses intended, and in harmony architecturally with the structure proper; such Committee to enter promptly on its work and report to this Board at an early meeting, recommending plans necessary to fully effect the improvements herein outlined, with detailed estimates of the total cost and a scheme for the rapid and complete execution of the plans recommended."

These were then adopted and subsequently Messrs. McNulty, Barnes, Skinner and Keeney, with President Howell, were constituted such Committee.

39. Construction plans, essentially as adopted February 13, 1888, for a new Brooklyn Station, located on the block bounded by Sands, Washington and High Streets, were prepared in course. The station proper for the Bridge Railway, was to be of two stories, and the connection with each of the two communicating elevated railroads by a third story, one over Sands and the other over High Street. This design is fully shown in elevation and plan by Figs. 12–21; work on it was suspended in June, 1888. After the adoption, May 14, 1889, of a plan for a new New York Station, the proper steps were taken to acquire the two pieces of property on Park Row needed and followed by condemnation proceedings; these were resisted in the court and the issue is still undecided.

40. The several plans hertofore adopted are alike in their general features, as exhibited in outline, Fig. 3. They embody the double slip system with forked transfer switches, heretofore described; the purposes in view governing their inception being as already set forth (§37); further description is to be found in the Reports to the Board of Trustees of the Committees presenting them. The prominent features in their design are to utilize the Stations now in use and to expand the traffic facilities at the terminals, until the full capacity of the double slip system with forked transfer switches is reached; then if the continued increase of travel over the Railway shall demand, perhaps to substitute

transfer loops for the switches, as shown for New York Station by Fig. 11; all of which however, as previously set forth, will in capacity fall short of that of the main lines over the structure itself.

Moreover, the sites thereby fixed for the Stations are unsuitable. In New York the Station proposed would be chiefly accessible from its outer or the street end, and the principal passages necessarily over the roadways on each side. Also from the location of the platforms, at the centre 375 feet back from Park Row, each passenger to or from the trains must walk at least 330 feet or $\frac{1}{16}$ mile further than if the location was close along Park Row; an aggregate of foot travel for the 34 300 000 passengers carried during the year 1889, of over 2 145 000 miles and equivalent to the march of a regiment of 1 000 soldiers from New York to St. Louis and return, or for over 85 days. In Brooklyn the terminal Station should be in the vicinity of the City Hall; a point at which connecting lines of elevated and street railways, from the conformation and development of the city, can most readily centre. A way Station in plan substantially as shown, Figs. 12–21, for a limited number of passengers, to or from that vicinity, may be placed at Sands Street. In each case, the Stations should be so designed and located, as to permit close connection with lines of communication in the two cities now in operation or hereafter to be built.

PLANS HEREIN PROPOSED.

41. Assuming that the designs heretofore adopted, as described above, exhaust the capacity of terminal stations arranged on the double slip system with forked transfer switches to relieve the occasional congestion of traffic on the Bridge Railway, studies have been made of other and different designs; of which that shown in outline, Fig. 6, was selected as comprising most that was desirable in the plan for such a Station. It embodies a modification of the triple slip system with transfer loops, shown in outline, Fig. 5; the loops being separated at the outer ends and joined by tangents, which form the branches of the main lines; and along these branches are placed the passenger platforms; the arrangement allowing the Station to be located close to and along the street.

42. The design and location of the Stations and the extension of the Railway in Brooklyn, are shown in Figs. 22–30; Fig. 22 and 23 being plans in outline located somewhat differently on Park Row, and Figs. 25–27, plans in detail of New York Station; Fig. 24 being

a plan of Brooklyn Terminal Station and of the lines of railway connecting it with the existing Bridge Railway, and Fig. 28 a plan of the Elevated Railroad floor in this terminal Station. Figs. 29 and 30 are elevations in perspective of the Stations proposed. They are located, each in an open space, and are surrounded by streets; that in New York being on the southerly side of Park Row, easterly of Frankfort Street, and with passages for vehicles and pedestrians connecting with William Street; and that for Brooklyn Terminal Station, on the northerly side of Myrtle Avenue, centrally over Adams Street and between Washington and Pearl Streets; a way Station in Brooklyn may be located near the one now used. The main lines of the Railway in Brooklyn from and beyond the Bridge entrance on Sands Street, are separated; the incoming lines being continued southward along the westerly side of Washington Street, to the curves entering the Station; and the outgoing lines from the curves leaving the Station, northerly over Pearl Street to the intersection with Nassau Street, and thence diagonally across the blocks and streets to the Bridge entrance. It should be stated that in fully developing the designs here presented, it will without doubt be found expedient to modify somewhat and perhaps to change entirely this choice of the sites for stations, particularly in Brooklyn, and of the location of the connecting lines of railway.

43. In New York, beginning at a point up the Approach at some distance from the present Station, the main lines are deflected outward, probably as shown Figs. 22 and 23, without however separating the three tracks; so as to include with the connecting curves, the three straight branch tracks within the Station and parallel with Park Row. In Brooklyn, beginning at the present tangent points in the main lines on the structure near Prospect Street, the three tracks are separated and laid parallel to each other over the remainder of the circuit.

44. The buildings for the terminal Stations as designed, are similar in plan and arrangement: each is 320 feet long and 130 feet wide; the ground floor, the second floor and a part of the third floor are devoted to the uses of the Bridge Railway and of the connecting elevated and surface railroads; the remaining floors—of which there are seven in New York, exclusive of those in the towers, and eight in Brooklyn—are set apart for such purposes as will ensure the largest income from rentals; the intent being that these buildings shall, independently of their public service, yield a fair

annual return on their cost, including that of the land they occupy. The arrangements for this service in each are essentially alike, and a description of the part used for a station in the building in New York will apply, except as noted, to that in the building in Brooklyn. On the ground floor is one large waiting room for passengers to and from the street, two suites of retiring rooms and two booths for the sale of tickets; on the second floor are the three branch tracks, 30 feet apart between centres, and four passenger platforms, each 225 feet long and 20 feet wide; and on the third floor is one large waiting room for passengers to and from the connecting elevated railroads, a suite of retiring rooms and two booths for the sale of tickets. Downward from each platform to the street floor are four stairways, two in the centre and one at each end, and upward in the centre to the elevated railroad floor, in Brooklyn Station are two stairways, as shown Fig. 28, and in New York Station is one stairway from each platform, except the outer, from which a direct passage leads to the elevated railroad, as shown Fig. 26. All stairways are 8 feet wide.

45. It will be seen that there is close and direct connection between the Bridge Railway and the elevated railroads at each Station, and ample and convenient accommodations for the passengers in transit from one to the other. How in Brooklyn, the elevated railroads shall reach the Station there, is not shown in the plans illustrated; provision should be made whereby the lines now operated and others to be constructed, may discharge passengers to and receive them from the Bridge Railway, as well as handle their trains at the Station, with equal facility and dispatch. Like considerations should determine the arrangements for the use of the connecting surface railroads; it being evident that whatever thus will best serve these various interests, will tend to increase the capacity and usefulness of the Bridge Railway.

46. The manner of running the trains into the Stations, the use of the passenger platforms and the movement of passengers, are illustrated by Fig 31, showing the three separate circuits of railway, A, B, C, and the Stations with their platforms; and Fig. 32, showing the trains discharging and receiving passengers, and the direction of movement. Generally, the incoming and outgoing platforms will be as designated, Fig. 32, and as "Ordinary" Fig. 31. On special occasions, when the travel is large and much the greatest in one direction, and sometimes, perhaps during the busy hours, morning

and evening, by opening or closing gates at the entrances to the stairways, shown on the street floor, Fig. 25, the common use of the two central platforms at the stations may be changed ; so that for instance, as indicated Fig. 31, during the morning hour there will be in use at Brooklyn Station three outgoing and one incoming platforms, and at the New York Station three incoming and one outgoing platforms ; and contrariwise during the evening hour. Referring to Fig. 32, it will be seen, that by causing the passengers arriving at a platform to leave the cars at the front and through one side door, and those at the same time departing from a platform to enter the cars at the rear and through the opposite side door, the movement will always be in one direction and without confusion.

47. It will be noticed, that at each Station, there are to receive and discharge passengers, when the three tracks are used, four platforms together 80 feet wide ; sixteen stairways downward to the street floor together 128 feet wide ; and in the Brooklyn Station eight stairways upward to the elevated railroad floor together 64 feet wide ; and that as the number of tracks used at the time is reduced to two or one, the ratio of these aggregate widths of platforms and stairways, to the travel over them, is thereby proportionately increased.

48. When the Bridge Railway is operated up to its maximum capacity, as herein described, a train will make a round trip in about 23 minutes, there will be 54 trains of four cars each in use, or 18 trains on each of the three railway circuits ; and the headway between trains on the main lines will be 25 seconds. By ceasing to operate one or two circuits, the time the trains remain at the platforms being unchanged, the capacity will be reduced one-third or two-thirds, and the headways between trains on the main lines will be increased to 37½ seconds, or to 1 minute 15 seconds, respectively. If desirable from the diminution of traffic, these headways may be increased while operating all or part of the circuits. To thus lessen the number of trains running, as the hourly traffic demands, the trains on a circuit to be cut out, may be left standing on the separated main tracks of that circuit, between the Bridge entrance and the Brooklyn Terminal Station, ready for movement whenever that circuit is again to be operated. Thus generally, whenever the variation of traffic during the day requires it, the number of trains to be moved may be reduced or increased one-third, two-thirds, or more, without switching or hauling the trains

from or to the main lines. Preferably the outer circuit, A, Figs. 27 and 31, should be used throughout the whole day; and the inner circuit, C, only during the busy hours morning and evening. For reserve and disabled cars, a storage yard in Brooklyn, located as shown, Fig. 24, outside of the loops and extending from the Bridge entrance, southerly parallel to Washington Street, is designed with transfer switches and tracks so arranged that cars to and from the yard, need not in any case be moved from or to the main lines, in face of the regular passenger trains.

49. To eliminate so far as possible, causes for stoppage and delay, and to promote safety in operating the Railway, as well as to reduce the cost of repairs and renewals, great care should be taken to provide a permanent road bed; the rails should be heavy and have rigid joints; on the curves and where the wear will be greatest, special fastenings, allowing quick removal of the worn rails or other parts, should be employed; at the switches and crossings, the connected lines should be continuous; and wherever derailment is likely to occur, there should be suitable guards or other appliances, to surely prevent a disabled car from leaving the line; also there should be an interlocking switch and signal system, more or less automatic in action and continued over the entire Railway. The cars should be light and strong in the body and have rigid trucks, specially strengthened to reduce side play; the brake system should be duplicate throughout; and the grips should be arranged to quickly seize and drop the cable, to hold it while the car is standing, and when applied, to automatically increase the pressure whenever the cable may begin to slip.

TYPICAL DIAGRAMS OF TERMINAL STATIONS.

FIGS 2-6.

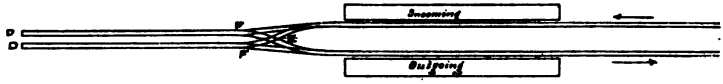


FIG. 2.

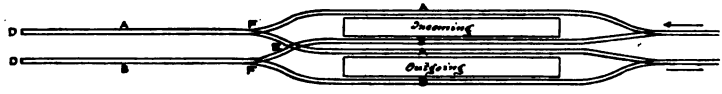


FIG. 3.

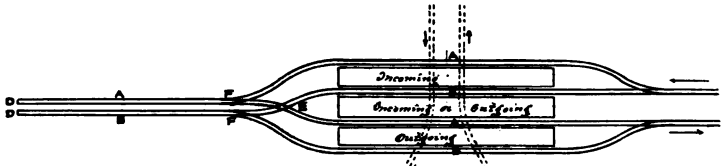


FIG. 4.

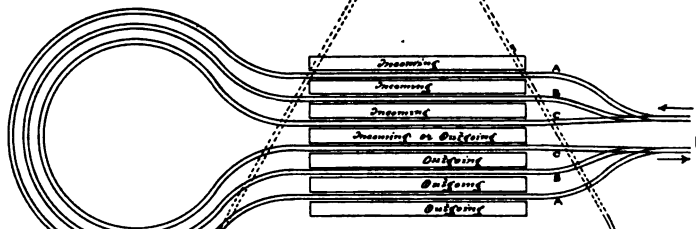


FIG. 5.

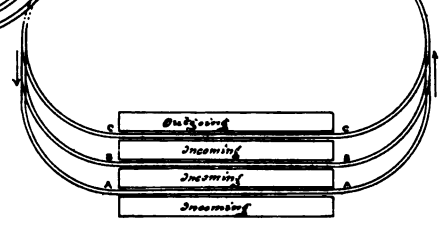
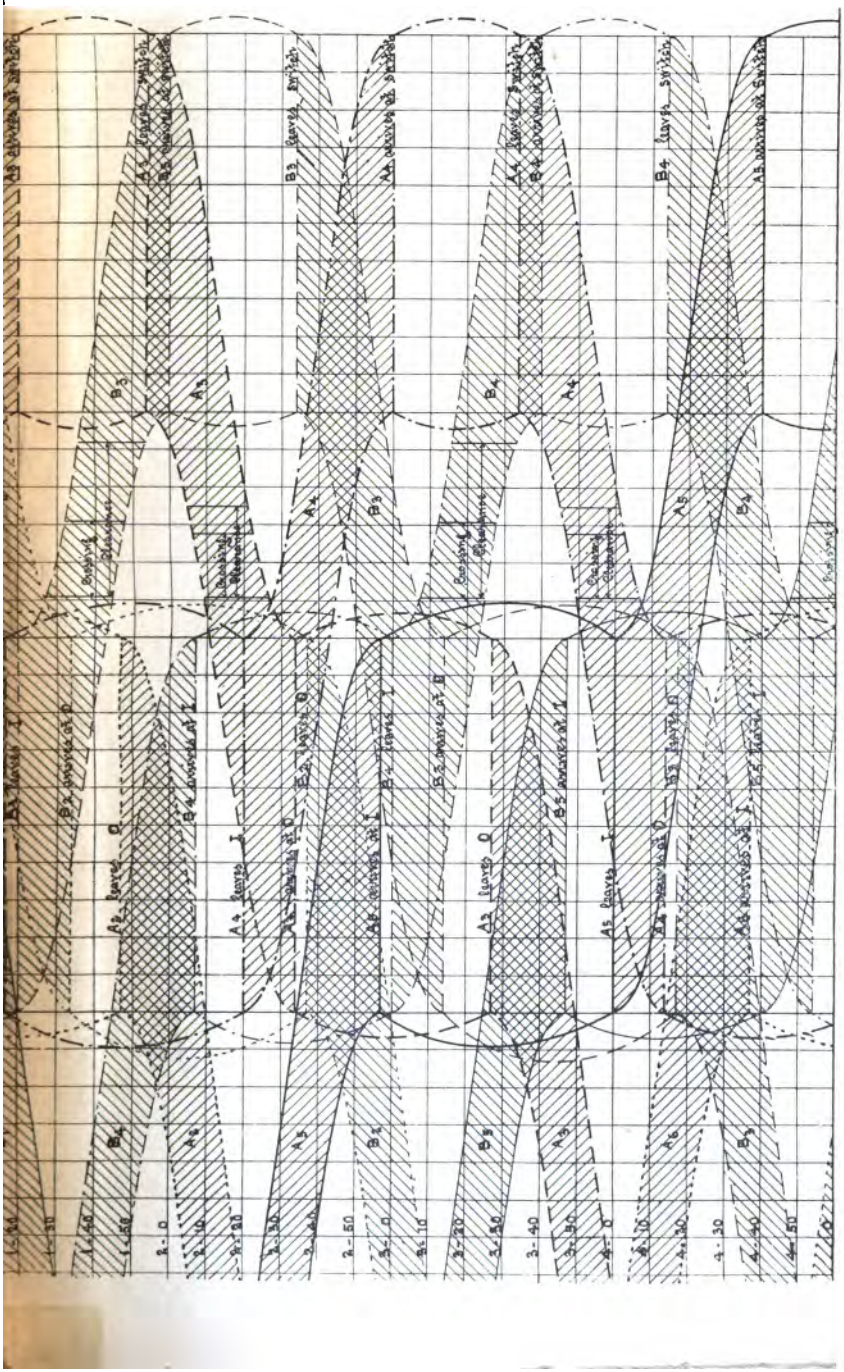


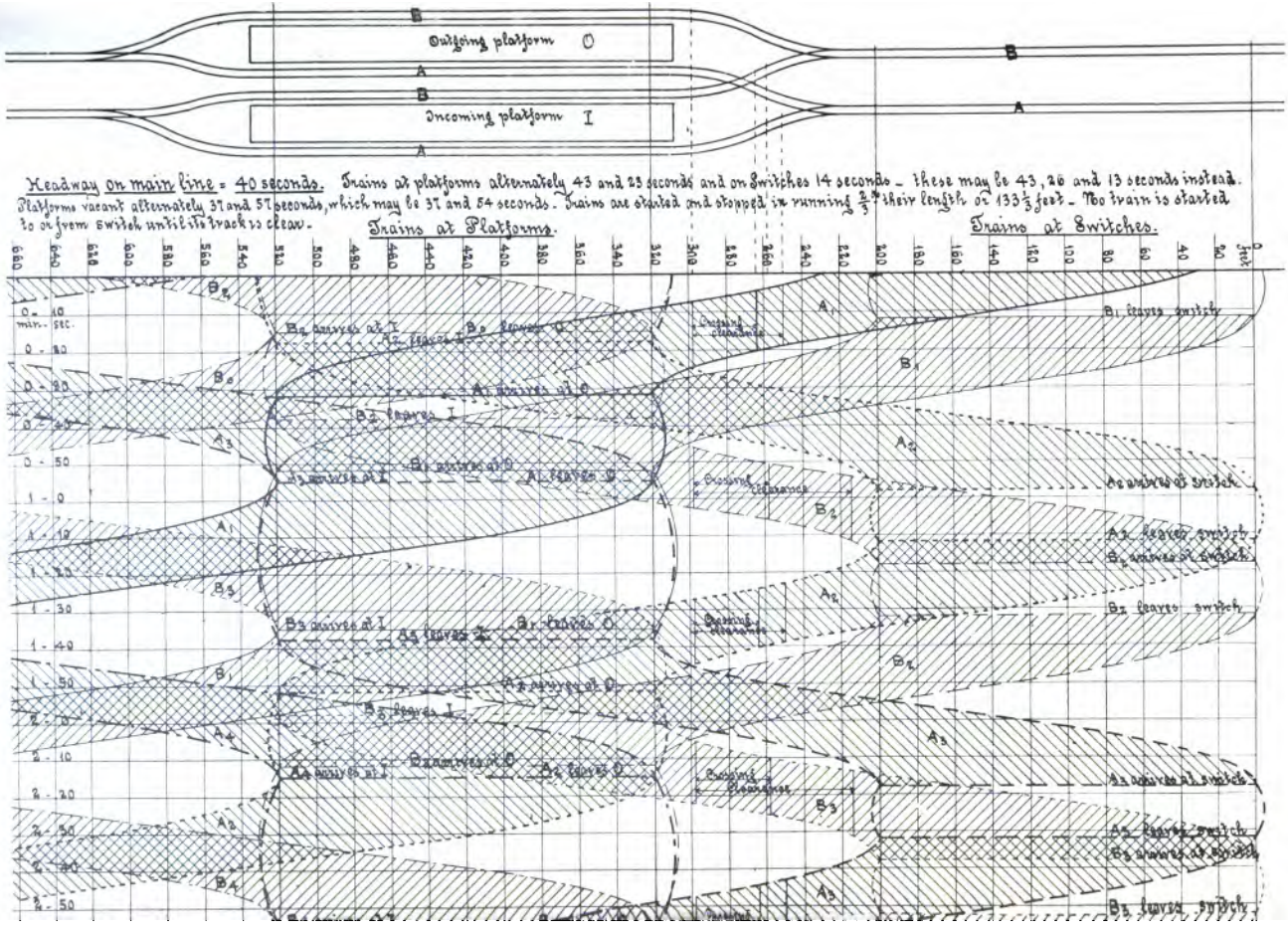
FIG. 6.

CONDS HEADWAY.

NG

FIG. 7.

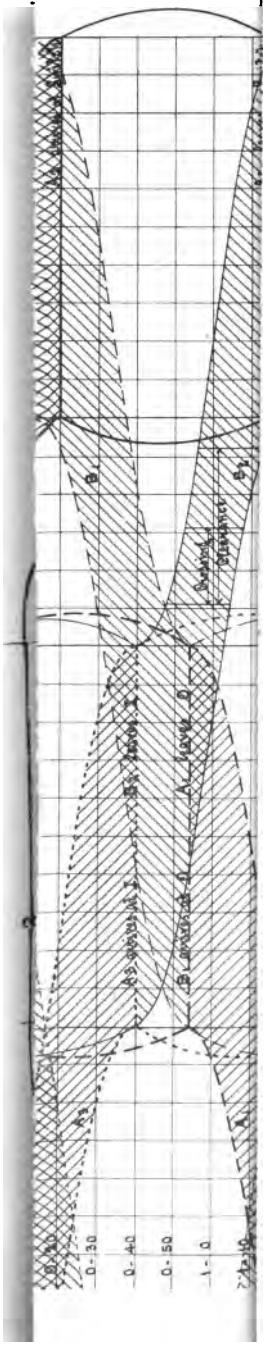




DIAGRAMS SHOWING

I DOUBLE SLIP

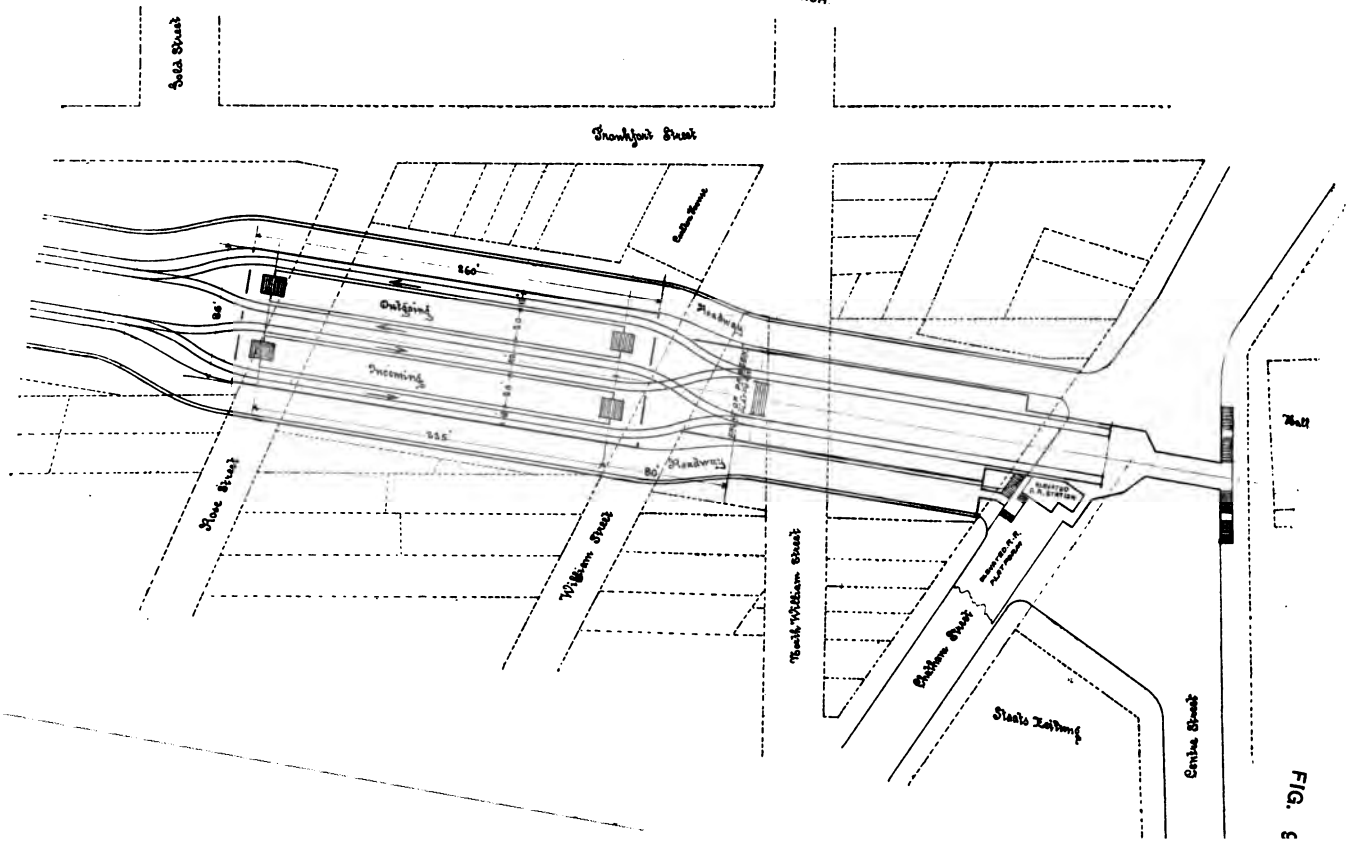
M IS MARKED 0.



NEW YORK STATION.—"PLAN A."

TWO SLIPS AND SWITCHES.

SCALE 120 FEET TO 1 INCH.


Gold Street
Snowhjort Street
Outgoing
Incoming
Roadway
Roadway
Roadway
Rose Street
William Street
North William Street
Pearl Street
Cedar Street
Water Street
Slip
Slip
Slip

BROOKLYN STATION.—"PLAN B."

TWO SLIPS AND SWITCHES.

SCALE 120 FEET TO 1 INCH.

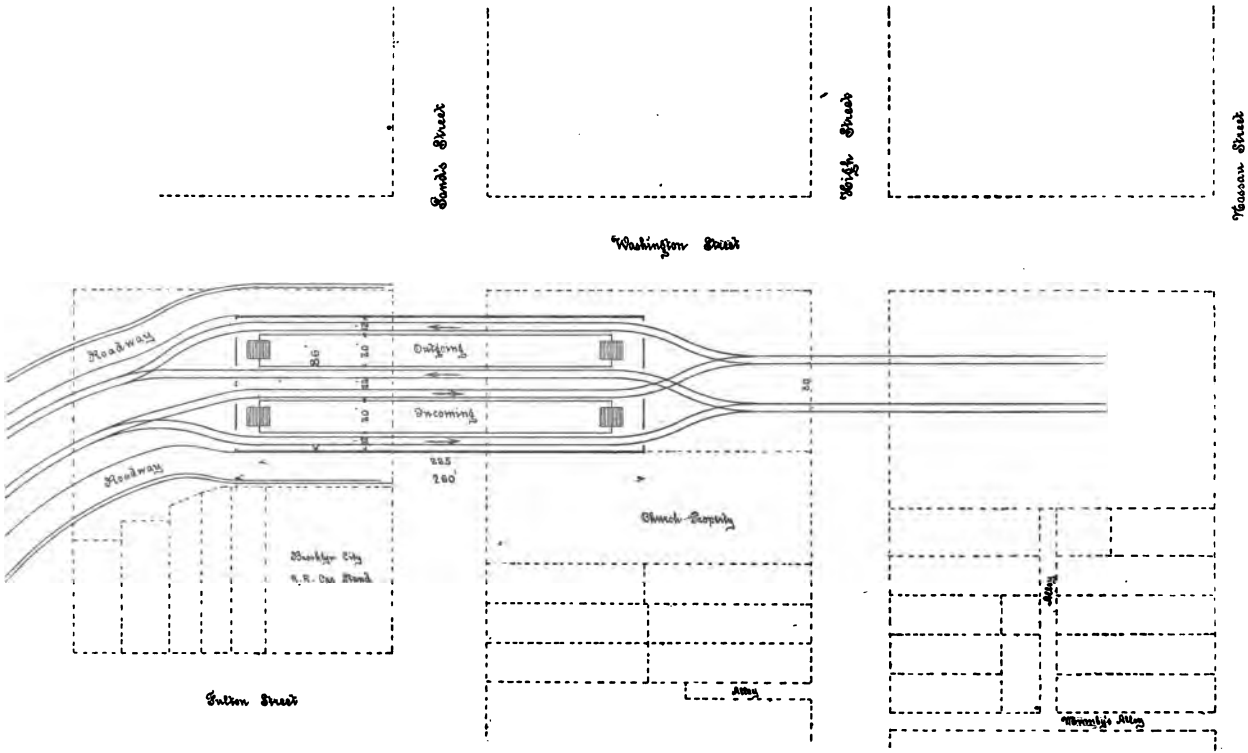


FIG. 10.

NEW YORK STATION.

TWO SLIPS AND LOOPS.

SCALE 120 FEET TO 1 INCH.

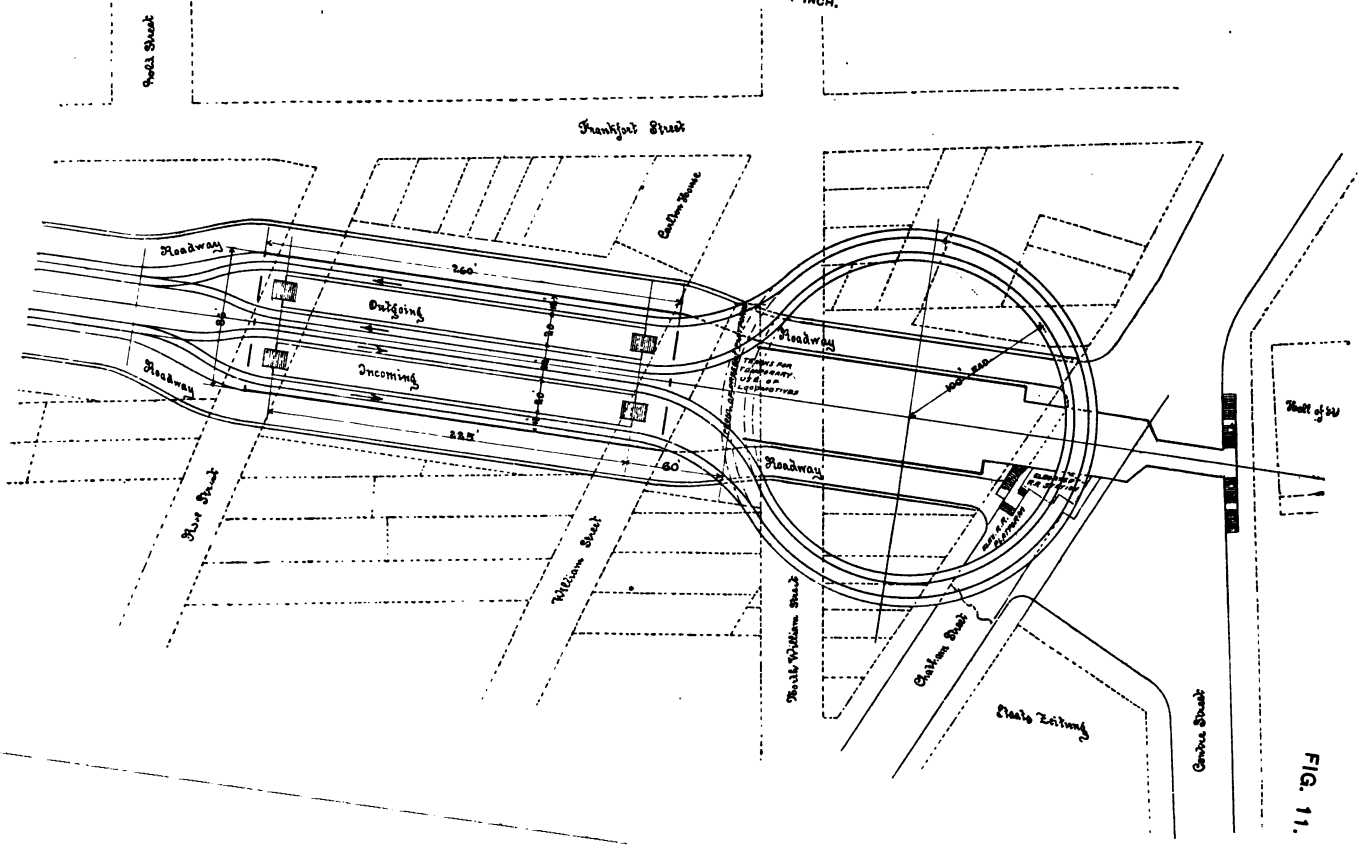
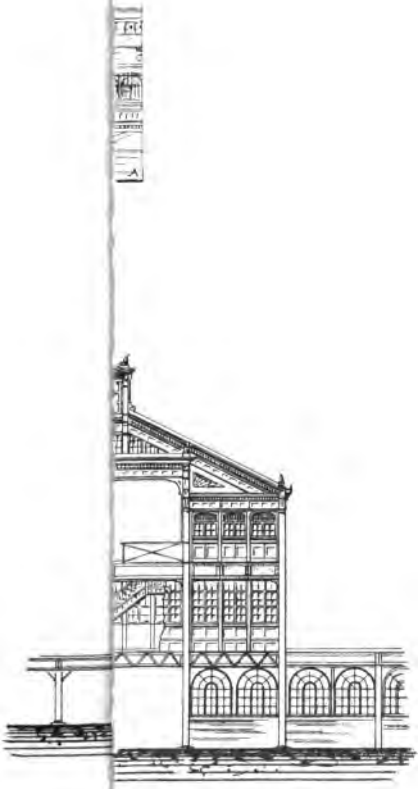


FIG. 11.

EEN HIGH AND SANDS



DESIGN FOR BROOKLYN STATION ON WASHINGTON

SCALE 40 FEE

FIG. 16.—LONGITU

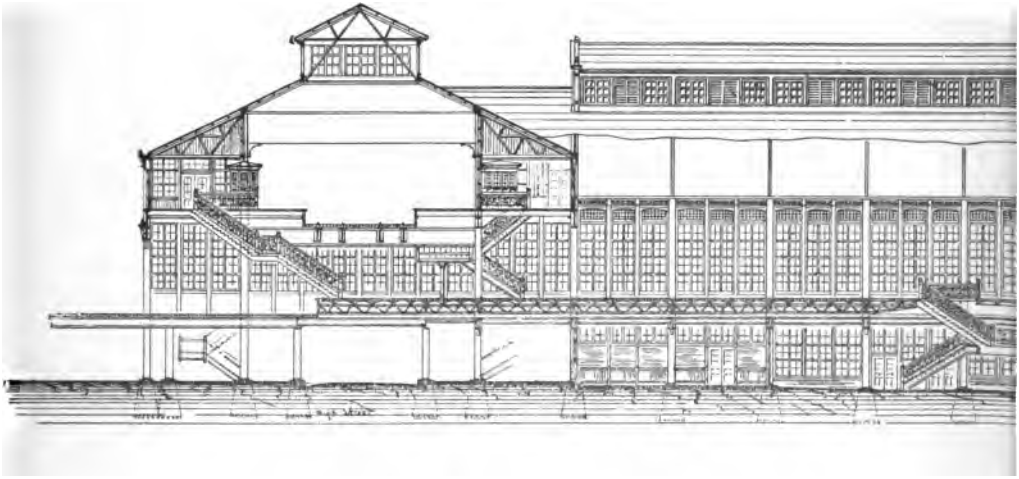


FIG. 17.—CENTRAL TRANSVERSE SECTION.

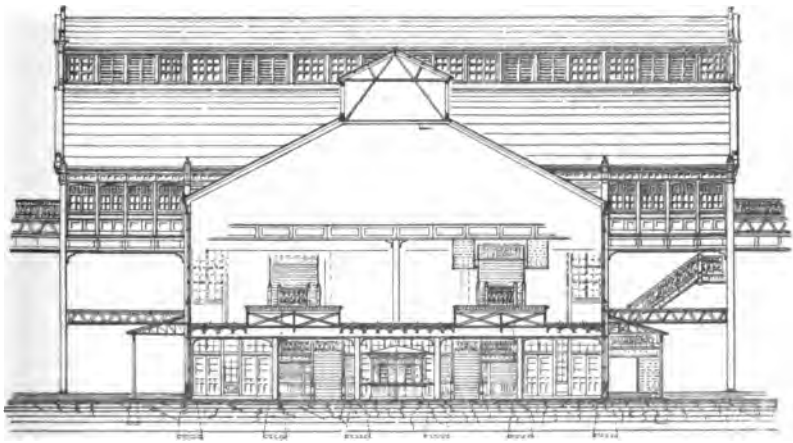
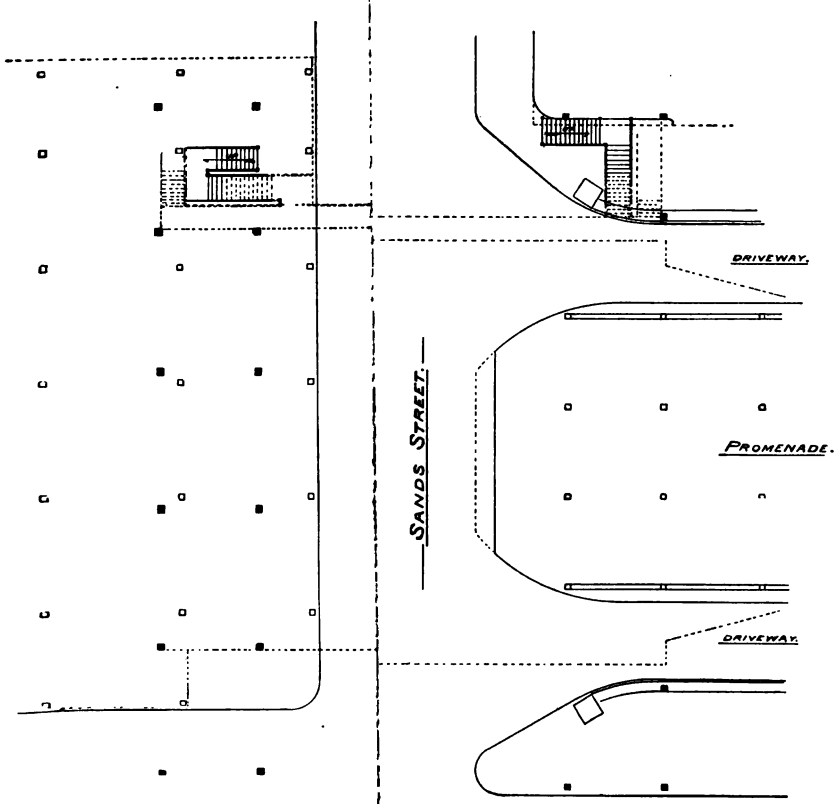



FIG. 19.